ANNALS OF THE UNIVERSITY OF ORADEA
FASCICLE OF TEXTILES, LEATHERWORK

AN ANALYSIS OF CONDUCTIVE FIBERS AS SMART TEXTILES

YUCE Ismail[1], YUKSELOGLU Muge[2], CANOGLU Suat[3]

[1] Trakya University, Edirne Technical Vocational High School, Textile, Clothing, Footwear and Leather Section, 22020, Edirne, Turkey, E-Mail: ismailyuce@trakya.edu.tr

[2] Marmara University, Faculty of Technology, Department of Textile Engineering, 34722, Istanbul, Turkey, E-Mail: myukseloglu@marmara.edu.tr

[3] Marmara University, Faculty of Technology, Department of Textile Engineering, 34722, Istanbul, Turkey, E-Mail: scanoglu@marmara.edu.tr

Corresponding author: YUCE, Ismail, E-mail: ismailyuce@trakya.edu.tr

Abstract: *This study aims to foreground the significance of conductive textiles as smart textiles for the clothing industry. As is known, smart textiles are materials and structures that sense and react to environmental changes. Conductive textiles have managed to become one of the fastest growing branches of smart textiles in that they have taken its place among the most leading products in recent years. As the literature review has shown, the significance of conductive textiles is mostly related to their wide range of usage areas such as medical, space, defense, industrial fields in which they create added value. Some of the studies have shown that electrical conductivity and static electricity are very important during the use and production of textiles. However, this study also wants to underline the probable disadvantages of static electricity for textiles products and/or their users. For this purpose, it has been explained that the generation of static charges or electrostatic behavior on the surface of textiles can lead to such disadvantages as electronical shocks of the consumer during product use or production process, breaking down of sensitive electronic devices, ignition in environments where flammable vapor and dust exists as well as rapid contamination of fabrics.*

In order to shed light on general features of conductive textiles, information regarding the basic principles of antistatic and conductive textiles, the methods of conductivity and their usage areas have been presented. To collect data, relevant literature has been reviewed by using qualitative research methods. After evaluating the collected data, it has been concluded that the fibers to which conductivity has been imparted are more suitable for the clothing industry.

Key words: *Smart, Static, Electricity, Conductivity, Fibers.*

1. INTRODUCTION

The real meaning of the word "electricity" comes from the word "amber" which means electrons in Greek. The materials are classified as conductive, semi-conductive and non-conductive (insulating) materials according to the state of electrical conduction. Electric history begins with the concept of electrostatic. Electrostatic can be defined as the electric charge of objects by friction. The earliest studies on electronics started with the static electronics studies of Milesian Thales during BC 600. Rubbing the amber against a wool baze, Thales observed that it pulled the chaff. He also realized that when it was pulled over a human body in long term rubbings, the amber produced small sparks. As a result of his experiments, he observed that mat and similar materials showed the same characteristics. Thales examined today's static electricity and the first mention of static electricity started during the Ancient Greek period of Thales. This is the first observation of static electricity by man. [1], [2].

All material in the environment consists of protons containing positive charges in the nucleus and containing an equal number of electrons surrounding the nucleus. The contact of two different materials allows the transfer of electrons across the interface. It causes the formation of charges on both materials after two materials have been separated. As a result, one material has negative charge (excess electrons) and the other material has positive charge (insufficient electrons). This is called static electrification. If the two materials are conductive, the charges can equalize themselves by the backflow of electrons immediately after the separation of two surfaces [3].

Static loads on the textile surface can lead to serious consequences. For example, loaded fibers and yarns may push each other, which makes processing difficult or impossible. Charges generated on fibers and fabrics can make sensitive electronic equipment difficult to operate and can sometimes overload and damage these devices. Discharges of sufficient magnitude may cause fires or explosion in an operating room. Therefore, it is necessary to prevent the formation of static charges and it is important to develop antistatic and conductive textiles.

Conductive textiles are also important for wearable electronic clothing, which is also a branch of smart textiles. Electronic textiles or e-textiles are used to specify fabric structures that integrate electronic elements into the textile, detect and respond to changes in the environment. These clothes are used such as defense, medicine, space, industry and so on. Conductive fibers, yarns and fabrics have functions such as sensor, electromagnetic protection, actuator, imaging, dust and bacteria prevention, static charge discharge, data management, communication [1], [4], [5].

Using wearable computers, we can communicate with the environment, receive and transmit data. The equipment designed for the desktop needs to be designed in a way that will fit the garment [6]. The Massachusetts Institute of Technology (MIT) issued a manifesto for this purpose:

> To date, personal computers have not lived up to their name. Most machines sit on the desk and interact with their owners for only a small fraction of the day. Smaller and faster notebook computers have made mobility less of an issue, but the same staid user paradigm persists. Wearable computing hopes to shatter this myth of how a computer should be used. A person's computer should be worn, much as eyeglasses or clothing are worn, and interact with the user based on the context of the situation. With heads-up displays, unobtrusive input devices, personal wireless local area networks, and a host of other context sensing and communication tools, the wearable computer can act as an intelligent assistant, whether it be through a Remembrance Agent, augmented reality, or intellectual collectives [7].

In this work, we focus on the properties of antistatic and conductive fibers. The fundamental principles of conductive textiles, conductive fiber production and types, future applications will be explained.

2. BASIC PRINCIPLES OF ANTISTATIC AND CONDUCTIVE TEXTILES

Fibers, yarns and fabrics are organic products that are not conductive. For this reason, the most important principle for antistatic and conductive textiles is to increase the ionic or electronic conductivity of the materials. Pure water is not conductive, but it has water conductivity that contains dissolved minerals, which plays a key role in ensuring conductivity to textile products. The

conductivity of these products can increase considerably with the presence of water molecules present in the textile materials [3], [8].
Antistaticity and conductivity can be imparted to a textile product using different methods. These methods are given below:

- During extrusion melting a synthetic polymer (PES, PA etc.) by adding conductive carbon or a metallic material,
- The production of yarns as a result of blending of stainless steel fibers or filaments with natural or synthetic fibers,
- Using conductive fibers made of metals such as stainless steel, aluminum, copper and carbon in production,
- Method of applying antistatic agents in a solution bath or by sputtering
- Electrolytic coating of the surface with metal or carbon [3], [9].

3. CONDUCTIVE FIBERS

The first step in the development of wearable electronic devices is to use electrically conductive fibers or yarns. Conductive fibers can be self-conducting or can be subsequently added. Carbon fibers are at the head of spontaneously naturally conductive fibers [1], [10]. In addition, fibers made from metallic materials such as stainless steel, ferro alloys, nickel, titanium, aluminum, copper wire are also used [5].

3.1. Carbon Fibers

Carbon fibers were first produced from cellulosic precursors by Edison and Swann more than 100 years ago [11]. Carbon is the nonmetal that forms the main element of coal and organic compounds. The raw materials of the carbon fibers are polymeric precursors materials such as polyacrylonitrile (PAN), cellulose, pitch and polyvinylchloride. The density of carbon fibers is in the range of 1.6-2.2 g / cm^3. Fatigue behavior of carbon fibers is better than all known metals. At the same time, the conductivity of tar-based carbon fibers is 3 times higher than copper. Major uses of carbon fibers include defense, space, automotive, and medical. [10], [12], [13].
Carbon filaments have high conductivity and good wear resistance. Carbon fiber can be produced singly or carbon particles can be incorporated in the extruder during fiber spinning (Figure 1). However, the conductivities of these fibers are limited. Homogeneous carbon fibers have high electrical conductivity in the range of 10^{-3}-10^{-5} Ohm.m. [6], [14].

Fig. 1 *Filament carbon fiber (HexTow®)*

3.2. Metallic Fibers

The first use of metallic fibers goes back 3000 years. Contrary to what is believed, the first man-made fibers are metallic fibers, not nylons or rayon [15]. 100% continuous metal wire causes various problems in the production and use of the fabric. It is also aesthetically undesirable. Because of this, it is preferred to use composite yarns, which are combined with various synthetic / natural fibers and yarns by different methods, in fabric production. Blending non-conductive fiber bands and metal bands can result in high-conductivity yarn. Blending of synthetic or natural fibers with metal fibers is successfully accomplished especially in staple spinning processes. Metallic fibers are typically produced either by a bundle drawing or a shaving operation. [1], [6], [5], [16]. The bundle-drawing process consists of bundling several fine metal wires then drawing them continuously and simultaneously from source metals. During shaving, the edges of a metal plate are shaved and afterwards winding in hanks or bobbins. This method is advantageous in that it requires less time and is less costly. At the same time, the section of the fibers obtained by this method is rectangular and is more crimp and finer than bundle-drawing method. The thickness of the metal fibers can be in the range of 1-80 μm. This value is lower than that of human hair with an average thickness of 70-100 μm. (Figure 2) [5], [14].

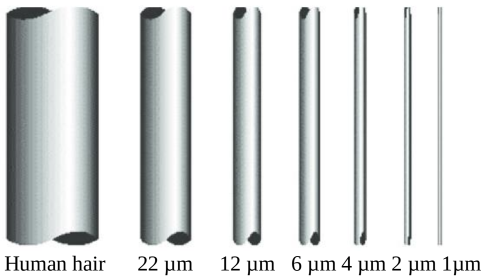

Fig. 2 *Metallic fiber diameters compared to human hair [17]*

3.3. Conductive Polymers

Polytiophene (PT), polyaniline (PANI) and polypyrrole (PPy) based polymers are conductive polymers. Conductive fibers were obtained using two experimental processes (melt spinning and coating process). The electrical conductivities of these polymers result from the fact that they have conjugated double bond structures. Polyaniline (PANI) is the most attractive conductive polymer because of its good environmental, thermal, chemical stability and economic properties. [5], [18].

3.4. Making Conductive Coating on Fibers

Electrically conductive fibers can be obtained by coating with conductors such as metal, metal oxides and metal salts. For this purpose, such coating methods as non-electric coating, vapor deposition, spraying can be applied without changing the existing properties of the textile products [1], [19].

Physical vapor deposition (PVD) and chemical vapor deposition (CVD) techniques have wide range of applications in industrial applications. Physical and chemical vapor deposition methods are effective methods for imparting conductivity to textiles. Metals such as Zn, Ti, Cu, Ag and Al; conductivity can be imparted to fibers. Silver (Ag) is a coating material that can impart conductivity, antibacterial, UV protection and hydrophobic properties to textile products (Figure 3) [20].

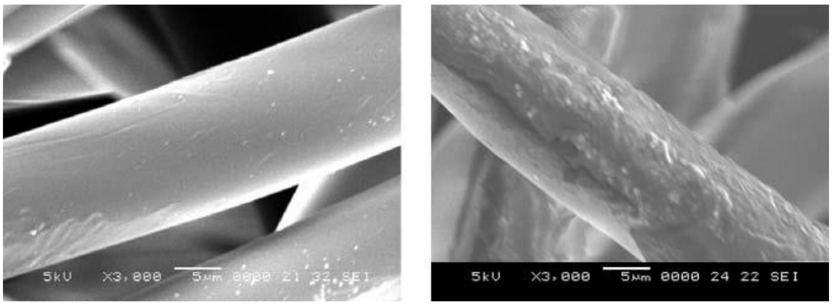

Fig. 3 *SEM images, (a) Original PP fibers, (b) 3 nm thick silver coated PP fibers [20].*

4. DISCUSSION

For the textile products to be conductive, the fibers from which they are made of need to be conductive. Depending on their raw materials, the fibers (carbon, metal fibers etc.) are spun in a way that will enable them to become conductive or this feature can be imparted to them later. It is important that the textile products used in clothing industry need to have some specific features that will provide the users with comfort. Metallic or carbon fibers are not suitable fibers because of their rigid properties. For this reason, it would be more appropriate to use conductive materials in extruder during fiber spinning or coat the surface with a conductive material so that the conductive fibers to be used in clothing production can fulfill their comfort features, which will consequently affect the comfort of clothes.

5. CONCLUSION

Being fast and practical is one of the most important factors in today's world. It is not possible for textile products not to be affected by this changing trend. For this reason, the importance of conductive textiles is continuing to increase day by day. Conductive textiles are now attracting considerable attention thanks to their innovative and life-promoting effects on human life.

Global competition is requiring antistatic and conductive textiles that can be produced at lower cost and greener production. It would be also advantageous to have textiles that are not only antistatic, but also have other functionalities such as soil and stain resistibility, retarding flame, water and/or oil repellency and antimicrobial ability.

In this work, the fundamental principles of conductivity and the conductivity of the fibers have tried to be explained. With the progress of technology, it is foreseen that the conductive polymers and coating technology will continue to develop in conductive fiber production.

REFERENCES

[1] A. C. Bedeloglu, N. Sunter and Y. Bozkurt, "*Elektriksel Olarak İletken Tekstil Yapıları, Üretim Yöntemleri ve Kullanım Alanları*", The Journal of Textiles and Engineer, vol. 17, pp. 7-17, 2010.

[2] M. Karayaman. (2013, March) "*İlkler Şehri Uşak'ta Elektriğin Serüveni*", [Online]. Available:https://www.academia.edu/10339782/%C4%B0lkler_%C5%9Eehri_U%C5%9Fakta_Elektri%C4%9Fin_Ser%C3%BCveni

[3] X. Zhang, "*Antistatic and Conductive Textiles*", in Functional textiles for improved performance, protection and health, Ed. N. Pan, G. Sun, Woodhead Publishing Ltd., 2011, pp. 27-44.

[4] S. Lam and P. Tang, "*Recent developments in flexible wearable electronics for monitoring applications*", Transactions of the Institute of Measurement and Control, vol. 29, pp. 283–300, 2007.

[5] M. G. Honarvar and M. Latifi, "*Overview of wearable electronics and smart textiles*" The Journal of the Textile Institute, 108:4, pp. 631-652, 2016.

[6] D. J. Tyler, "*Joining of wearable electronic components*", in Joining textiles Principles and applications, Ed. I. Jones, G. K. Stylios, Woodhead Publishing Ltd. 2013, pp. 507-535.

[7] Available: https://www.media.mit.edu/wearables/

[8] O. Kayacan and E. Y. Bulgun, "*Akıllı Tekstiller ve Elektriği İleten Tekstil Esaslı Malzemeler*", The Journal of Textiles and Engineer, vol. 58, pp. 29-34, 2005.

[9] D. Cukul, "*Teknik İpliklerde Son Yıllardaki Gelişmelere Örnekler*", The Journal of Textiles and Engineer, 20: 91, pp. 50-63, 2013.

[10] B. Yalcinkaya, D. Yilmaz, "*Elektronik Tekstillerin, Tekstil Endüstrisindeki Yeri ve Giyilebilir Tekstilde Kullanılan İletken Lifler*", Tekstil Teknolojileri Elektronik Dergisi, vol. 5, pp. 61-71, 2011.

[11] B. A. Newcomb and H. G. Chae, "*The properties of carbon fibers*", in Handbook of Properties of Textile and Technical Fibres, Ed. A. R. Bunsell, The Textile Institute Book Series, 2018, pp. 841-871.

[12] N. Yaman, T. Oktem and N. Seventekin, "*Karbon Liflerinin Özellikleri ve Kullanım Olanakları*", Tekstil ve Konfeksiyon, vol. 2, pp. 90-95, 2007.

[13] P. Morgan, "*Carbon Fibers and Their Composites*", Taylor & Francis, 2005.

[14] N. Sunter, "*İletken İpliklerin Üretim Yöntemlerinin ve Özelliklerinin İrdelenmesi*", Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İzmir, 2011.

[15] L. Guo, T. Bashir, E. Bresky and N. K. Persson, "*Electroconductive textiles and textile-based electromechanical sensors—integration in as an approach for smart textiles*", in Smart textiles and their applications, Ed. V. Koncar, Woodhead publishing in textiles no. 178, 2016, pp. 657-693.

[16] H. G. Ortlek, G. Kilic, G. Okyay and O. Bilget, "*Paslanmaz Çelik Tel İçerikli Özlü İplik Üretimi İçin Farklı Ring Eğirme Metodlarının İncelenmesi*", Textile and Apparel, vol. 3, pp. 225-235, 2011.

[17] E. J. Leavline, D. A. A. G. Singh, S. Prasannanayagi and R. Kiruthika, "*A Compendium of Nano Materials and their Applications in Smart Nano Textiles*", Research Journal of Nanoscience and Nanotechnology, vol. 5, pp. 44-59, 2015.

[18] B. Kim, V. Koncar, E. Devaux, C. Dufour and P. Viallier, "*Electrical and morphological properties of PP and PET conductive polymer fibers*", Synthetic Metals, vol. 146, pp. 167–174, 2004.

[19] B. J. Munro, J. R. Steele, T. E. Campbell and G. G. Wallace, "*Wearable biofeedback systems*", in Intelligent textiles and clothing, Ed. H. Mattila, Woodhead Publishing Ltd., 2014, pp. 450-470.

[20] I. Yuce, S. Canoglu, M. Yukseloglu, "*Textile Surface Modification by Pyhsical Vapor Deposition – (Review)*", Annals of the University of Oradea Fascicle of Textiles, Leatherwork, pp.123-128, 2017.